(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 725 474 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
07.08.1996 Bulletin 1996/32

(51) Int. Cl.^{6}: **H02K 51/00**, B60L 11/12, B60K 17/12, B60K 6/04

(21) Application number: **96101275.4**

(22) Date of filing: **30.01.1996**

(84) Designated Contracting States:
DE FR GB

(30) Priority: **31.01.1995 JP 13700/95**
31.01.1995 JP 13699/95
08.06.1995 JP 141744/95
09.06.1995 JP 142991/95
09.06.1995 JP 142993/95

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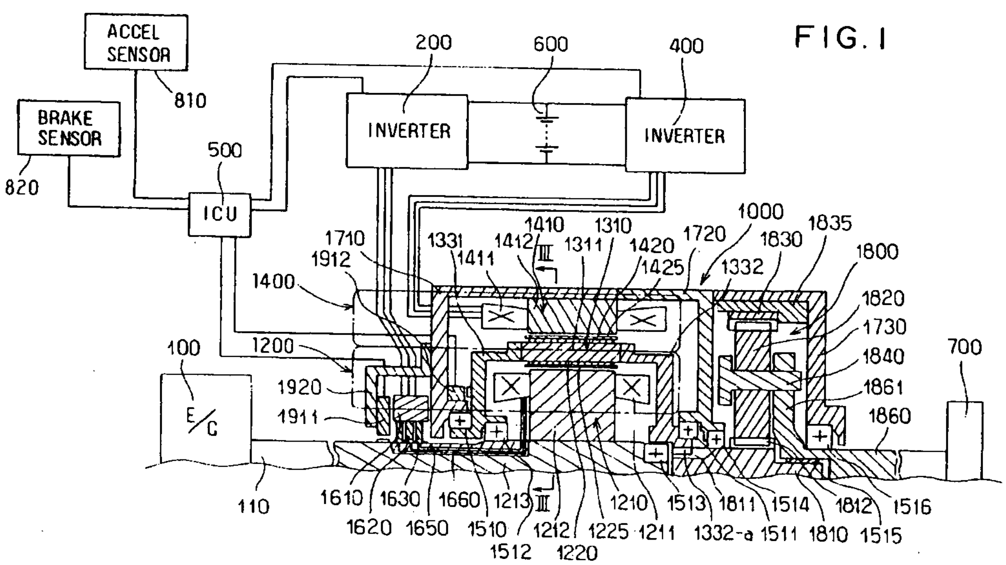
(54) System and method for driving electric vehicle

(57) A torque-speed converter (1000) is composed of a first rotor (1210) which has a first control coil (1211), a second rotor (1310) and a stator which has a second control coil (1411). The second rotor (1310) has a first magnetic field member (1220) such as permanent magnets which supplies the first control coil (1211) with magnetic field and a second magnetic field member (1420) such as permanent magnets which supplies the second control coil (1411) with magnetic field. The first and second control coils are energized to drive the second rotor (1310) to rotate at a set speed with a set torque according to vehicle running condition. The first and the second control coil are also energized to generate battery charging current when the vehicle speed is decreased and the second rotor (1310) is driven by the vehicle wheels.

FIG. 1



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Description

CROSS REFERENCE TO RELATED APPLICATION

The present application is based on and claims priority from Japanese Patent Applications Hei 7-13699, filed on January 31, 1995, Hei 7-13700 filed on January 31, 1995, Hei 7-141744 filed on June 8, 1995, Hei 7-142991 filed on June 9, 1995 and Hei 7-142993, filed on June 9, 1995, the contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a system and method for driving an electric vehicle and, more particularly, relates to a hybrid-type electric-vehicle-driving system with electric power generated by an internal combustion engine.

2. Description of Related Art

Japanese Patent Laid-Open Sho 60-1069 discloses a hybrid-type electric-vehicle-driving system with electric power generated from an internal combustion engine. Such an electric-vehicle-driving system is composed of a generator which is mechanically connected to a drive shaft of an internal combustion engine, an electric motor for driving vehicle wheels, battery unit for storing electric power of the generator and energizing the electric motor and a control unit for regenerating electric power by the electric motor when the vehicle speed is reduced.

However, since all the driving power of the above conventional system is applied to the wheels through electric power system including the generator, the battery unit and the motor, the power system is necessarily required to have a large size. In addition, since the energy conversion is made a plurality of times, the total efficiency of the system is not so high.

Japanese Patent Laid-Open Sho 58-130704 discloses a torque-speed converting system, in which engine power is converted into electro-magnetic induction force and transmitted to the vehicle wheels by a wheel-drive motor having control coils and, as required, electric power is supplied from a battery to the wheel-drive motor, or kinetic energy of the vehicle is converted by the wheel-drive motor (functions as a generator) to electric power to be stored into a gyro wheel.

However, since the frequency of the induction current applied to the control coils (short-circuited coils) of the dirive-motor is proportional to the engine rotational speed and can not be changed, it is not possible to control the rotational speed of the vehicle wheels although the torque can be changed.

SUMMARY OF THE INVENTION

In view of the above described circumstances, it is a primary object of the present invention to provide an improved system and method for driving an electric vehicle in which a portion of the engine power is transmitted directly to the wheels with the remainder converted into electric power so that both torque and rotational speed of the wheels can be changed, thereby increasing efficiency of the system.

Another object of the present invention is to provide a system for driving an electric vehicle which comprises an improved torque-speed converter (hereinafter referred to as T-S converter) composed of a first rotor having a first control coil, a stator having a second control coil, a second rotor having first and second members for generating magnetic field interlinking respectively the first and second control coils. The system further comprises rotation sensor for detecting rotation of the first rotor and the second rotor and means for supplying the first and second control coils with control electric current according to the rotation of the first and second rotors so that the T-S converter converts rotational speed and torque of the engine into a set rotational speed and a set torque of the vehicle drive member.

Another object of the present invention is to provide a system for driving an electric vehicle wherein the T-S converter further comprises a speed reduction means. The speed reduction means may comprise planetary-gears.

Another object of the present invention is to provide a system for driving an electric vehicle wherein the control current supplying means controls the engine to operate as a brake member when the vehicle drive member drives the output shaft.

Another object of the present invention is to provide a system for driving an electric vehicle wherein the first rotor, the second rotor and the stator are disposed coaxially with each other.

Another object of the present invention is to provide a system for driving an electric vehicle wherein at least one of the first and second members are permanent magnets. The remainder may be a squirrel cage conductor.

A further object of the present invention is to provide a method for driving an electric vehicle which comprises steps of calculating a set torque Tv and set angular speed ωv of a vehicle drive member, detecting output torque Te and angular speed ωe of the engine, supplying the first and second control coils with control electric current according to differences between the torques Tv and Te and between the angular speeds ωv and ωe thereby to convert torque Te and angular speed ωe of the engine into the set torque Tv and set angular speed of the vehicle drive member.

A current control step can be added to generate battery charging current when the angular speed ωe of the engine is higher than the set angular speed ωv and

the output torque Te of the engine is larger than the set torque Tv.

Another current control step can be added to generate driving torque when the angular speed ωe of the engine is lower than the set angular speed ωv and the output torque Te of the engine is lower than the set torque Tv.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and characteristics of the present invention as well as the functions of related parts of the present invention will become clear from a study of the following detailed description, the appended claims and the drawings. In the drawings:

Fig. 1 is a schematic cross-sectional side view illustrating a system according to a first embodiment of the present invention;
Figs. 2A, 2B, 2C and 2 D are graphs showing how the system according to the first embodiment converts torque and rotational speed of the engine into set torque and rotational speed of the vehicle;
Fig. 3 is a cross-sectional schematic view illustrating a main portion of a T-S converter of the system cut along a line III-III in Fig. 1;
Fig. 4 is a cross-sectional plan view illustrating a main portion of a T-S converter of the system according to the second embodiment;
Fig. 5 is a schematic cross-sectional side view illustrating a system according to a third embodiment of the present invention;
Figs. 6A, 6B, 6C and 6D are graphs showing how the system according to the third embodiment converts torque and rotational speed of the engine into set torque and rotational speed of the vehicle;
Fig. 7 is a schematic cross-sectional side view illustrating a system according to a fourth embodiment of the present invention;
Fig. 8 is a flow chart of steps for controlling a system according to the present invention;
Fig. 9 is a flow chart of a sub-routine of a step in the flow chart shown in Fig. 8;
Fig. 10 is a flow chart of a sub-routine of a step in the flow chart shown in Fig. 8;
Fig. 11 is a schematic cross-sectional side view illustrating a system according to a fifth embodiment of the present invention;
Fig. 12 is a schematic cross-sectional side view illustrating a system according to a sixth embodiment of the present invention;
Fig. 13 is a schematic cross-sectional side view illustrating a system according to a seventh embodiment of the present invention;
Fig. 14 is a schematic cross-sectional side view illustrating a portion of the system shown in Fig. 13; and
Figs. 15A, 15B, 15C, 15D, 15E and 15 F are cross-sectional views illustrating variations of a second rotor of the V-S converter according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

(First Embodiment)

A system for driving an electric vehicle according to a first embodiment of the present invention is described with reference to Fig. 1.

A torque-rotational speed converter 1000 (T-S converter) is a driving unit which is driven by an engine 100 to drive vehicle wheels 700 at driving torque and rotational speed controlled according to vehicle driving conditions. The T-S converter is composed of a speed control section 1200 which is a synchronous motor structure to be described later, a torque control section 1400 which is another synchronous motor structure to be described later and a speed reduction section 1800. An inverter 200 has power switching transistors (not shown) therein and converts the DC-current supplied from a battery 600 into three phase AC current, which is supplied to the speed control section 1200 of the T-S converter. The inverter 200 also converts AC current generated by the speed control section 1200 into DC current to charge the battery 600 when the speed control section 1200 is driven by the vehicle wheels 700. An inverter 400 also converts DC current into AC current and AC current into DC current between the battery 600 and the torque control section 1400 of the T-S converter 1000 in the same manner as the inverter 200. An inverter control unit 500 controls the inverters 200 and 400 according to signals transmitted from an accelerator sensor 810, a brake pedal sensor 820, rotation sensors 1911 and 1912 (to be described later) and other sensors. Joint members and speed reduction mechanisms, which are used in the ordinary vehicle, may be disposed between the engine 100 and the T-S converter 1000, and also between the T-S converter 1000 and the wheels 700. An engine shaft 110 of the engine 100 is connected to an input shaft 1213 of the T-S converter 1000 through a coupling (not shown).

The T-S converter 1000 is composed of a pair of cylindrical outer frames 1710 and 1720, a cylindrical first rotor 1210 which is carried by the input shaft 1213, a second rotor 1310 which is rotatably disposed around the first rotor 1210 at a gap and a stator 1410 fixed to an inner periphery of the outer frame 1710. The input shaft 1213 extends from the center of an end of the outer frame 1710 and is connected with the engine shaft 110. The stator 1410 has a stator core and a control coil 1411 which generates a rotating magnetic field when energized by the inverter 400. The first rotor 1210 has a rotor core 1212 and a control coil 1211 which forms a rotating magnetic field. A brush holder 1610, three brushes 1620 and three slip rings 1630 are disposed in a cover case 1920 to supply three phase electric power to the control coil 1211 of the first rotor 1210. Shaft sup-

porting members such as bearings 1510 and 1511 are fixed to the driven shaft 1213. The control coil 1211 and the slip ring 1630 are connected by lead wires 1660 passing under the bearing 1512 with an insulating member 1650. The insulating member 1650 is inserted in a groove formed in the input shaft 1213 so as to go under the bearing 1512. The second rotor 1310 has a hollow rotary yoke 1311 and a plurality of internal permanent magnets 1220 are fixed to the inner periphery thereof by a ring 1225 at an equal interval to provide N and S poles alternately. The hollow rotary yoke 1311 is supported by the outer frames 1710 and 1720 via rotor frames 1331 and 1332 and bearings 1510 and 1511. The input shaft 1213 is rotatably supported by the rotor frames 1331 and 1332 via bearings 1512 and 1513. The permanent magnets 1220, the rotor core 1212 and the control coil 1211 compose a synchronous motor which corresponds to the aforementioned speed control section 1200. The second rotor 1310 also has a plurality of external permanent magnets 1420 fixed to the outer periphery of the hollow rotary yoke 1311 by a ring 1425 at an equal interval to provide N and S poles alternately. The permanent magnets 1420, the stator core 1412 and the control coil 1411 compose a synchronous motor which corresponds to the aforementioned torque control section 1400. The rotation sensors 1911 and 1912 are disposed respectively in the cover case 1920 and in a space between a rotor frame 1331 of the second rotor 1310 and the outer frame 1710. The sensor 1911 and 1912 are connected to the inverter control unit 500 to control rotational speed and torque of the first and second rotors 1210 and 1310 as described later.

The speed reduction Section 1800 of the T-S converter 1000 has a sun gear shaft 1810, a planetary gear 1820, an internal gear 1830, a planetary gear shaft 1840 and an output shaft 1860. An input gear 1811 is formed on an end of the sun gear shaft 1810 in mesh with an internal gear 1332a of a boss portion of the rotor frame 1332. The sun gear shaft 1810 is rotatably supported by the outer frame 1720 and the output shaft 1860 respectively via bearings 1514 and 1515. The rotation is transmitted from the second rotor 1310 to the output shaft 1860 through the sun gear shaft 1810, a sun gear 1812 formed around the sun gear shaft 1810 in mesh with the planetary gear 1820. The rotational speed is reduced by the internal gear 1830 and the planetary gear shaft 1840, and is transmitted to a planetary gear carrier portion 1861 formed integrally with the output shaft 1860. The output shaft 1860 is rotatably supported by a bearing 1516 which is fitted to a boss portion of a frame 1730 of the speed reduction section 1800. The sun gear shaft 1810 and the output shaft 1860 are disposed in line with the input shaft 1213. The internal gear 1830 is fixed to the frame 1730 of the reduction section 1800 via a fixing member 1835.

Operation of the T-S converter 1000 is described with reference to a flow chart shown in Fig. 8.

When the inverter control unit 500 is started, a set-torque Tv for the vehicle wheels 700 is determined according to a signal representing the throttle-open-angle detected by the accelerator sensor 810 and a signal representing brake-pedal-operation detected by the brake pedal sensor 820 in a step S100. Then, angular speeds ωe of the first rotor 1210 and ωv of the second rotor 1310 are determined according to signals from the rotation sensors 1911 and 1912 in a step S102. Subsequently, engine torque Te generated by the engine 100 is calculated from the throttle-open-angle signal and the angular speed signal ωv on the basis of a data map of the inverter control unit 500 (step S104). Transmitting torque Tt which is transmitted between the first rotor 1210 and the second rotor 1310 is determined in the following step. The transmitting torque Tt is set to be equal to the engine torque Te. That is, no addition to or reduction from the engine torque Te is made between the first and second rotors 1210 and 1310 except a slight torque change in order to maintain the drive-stability of the vehicle. In order to eliminate the slight torque change between the first and second rotors 1210 and 1310, rotational speed of the second rotor 1310 is controlled by the inverter 200.

Then toque T2 for the torque control section 1400 to supplement difference between the transmitting torque Tt and the set torque Tv is determined in a step S106. That is, the relationship of the torque is expressed as $T2 = Tv - Tt = Tv - Te$. Subsequently, the inverter 400 controls the torque control section 1400 to generate the supplemental torque T2 in a step S108.

The torque control section 1400 operates as a generator or a motor according to a difference between the engine torque Te and the set torque Tv in the step S 106 as shown in Fig. 9.

When the engine torque Te is detected smaller than the set torque Te in a step 1060, the process goes to a step 1062 where the torque control section 1400 is controlled to become a wheel-drive motor which generates the torque $T2 = Tv - Te$ with power supplied from the inverter 400. If the engine torque Te is detected larger than the set torque Tv on the other hand, the process goes to a step S1064, where the torque control section 1400 is controlled to become a generator which is driven by the torque $T2 = Te - Tv$. If the engine torque Te is equal to the set torque Tv, the torque control section 1400 does not function as a motor or a generator.

The engine torque Te may be calculated from the brake-pedal-operation signal transmitted from the brake pedal sensor 820 as shown in Fig. 10. When the vehicle is driven on a steep slope and the brake pedal is operated to a degree more than a predetermined degree, fuel supply to the engine is stopped thereby to stop driving the first rotor 1210 in a step S1044. Then, the set torque Tv is calculated only from the brake pedal signal in a step S1046, and a negative value of the engine torque Tv at an angular speed ωe is calculated in a step S1048 so that the inverter 400 controls the torque control section 1400 to operate as a regenerative brake.

When the brake pedal is determined to operate within the predetermined degree in the step S1040 on

the other hand, the torque Te is calculated in the ordinary manner from the throttle-open-angle signal, the angular speed ωe and etc. in a step S1042.

Then, charging state of battery 600 is detected by a well-known manner (for example, by calculating from battery voltage and charging current) in a step S 110 in Fig. 8. If the charging ratio is higher than a maximum value, the control of the first rotor by the inverter 200 is stopped and only the control by the torque control section 1400 is permitted. At this time, the fuel supply to the engine 100 is cut or reduced in a step S112. Then, the process returns to the step S100 if the charging ratio is detected not lower than a minimum value in a step S114. When the battery charging ratio is not higher than the maximum value on the other hand, the process goes to a step S114, and to a step S116 if the battery charging ratio is lower than the minimum value. The process returns to the step S100 after the fuel supply to the engine 100 is increased in the step S116.

The transmitting torque Tt is controlled to substantially equal to the engine torque Te by the speed control section 1200 according to the above embodiment. However, it is possible to control the second rotor 1310 to rotate at a speed higher than the first rotor 1210, while the torque is maintained constant. That is, the frequency of the AC current supplied by the inverter 400 to the stator 1410 is increased to corresponds to the rotational speed of the second rotor and the frequency of the AC current supplied by the inverter 200 to the second rotor 1310 is controlled to correspond to a difference between the rotational speeds of the first rotor 1210 and the second rotor 1310.

Operation of the T-S converter 1000 when the engine rotates at a speed 2n [rpm] with a torque t [N • m] and the vehicle runs at a speed n [rpm] with a torque 2t [N • m] is described with reference to Fig. 1, Figs. 2A through 2D and Fig. 3. The speed and the torque of the engine and the vehicle wheels are treated here as if the engine and the wheel were connected directly in order to make the discussion simple.

Since the second rotor 1310 is mechanically connected to the output shaft 1860 via the reduction section 1800, the rotational speed of the second rotor 1310 must be controlled by the speed control section 1200 to correspond to the vehicle speed.

The engine rotation at the speed 2n [rpm] with the torque t [N • m] shown in Fig. 2A is transmitted to the input shaft 1213 of the T-S converter 1000 through a coupling (not shown), and to the first rotor 1210. The rotational speed 2n [rpm] of the second rotor 1310 is reduced to n [rpm] by induction force or electromagnetic force of the speed control section 1200 and transmitted to the vehicle wheels 700 as shown in Fig. 2B.

In order to change the speed of the second rotor 1310 from 2n [rpm] to n [rpm] while maintaining the same torque t as shown in Fig. 2B, the direction F of the rotation of the second rotor 1310 relative to the first rotor 1210 becomes opposite to the direction E of the torque of the second rotor as shown in Fig. 3. (Incidentally, an arrow G indicates the direction of the engine torque, and an arrow H indicates the direction of the torque from the vehicle wheels.) The speed control section of the T-S converter 1000 operates in the generating mode at this moment. The rotation of the second rotor 1310 relative to the first rotor 1210 is detected by the rotation sensors 1911 and 1912 and the control coil 1211 of the first rotor 1210 is energized at timing calculated on the basis of the relative rotation. The power generated in the control coil 1211 of the first rotor 1210 is supplied to the the battery 600 and to the torque control section 1400 through the slip rings 1630, the brushes 1620. Thus, the second rotor 1310 rotates the output shaft 1860 at the speed n [rpm] with the torque t [N • m] to generate energy nt [N • m][rpm] as indicated by cross hatching in Fig. 2B. In other words, the T-S converter 1000 can transmit the driving torque t of the engine to the vehicle wheels 700 without change and generates electric power by the difference in the rotation between the engine 100 and the vehicle wheels 700.

Then, the inverter 400 supplies the stator control coil 1411 of the torque control section 1400 with AC control current at timing calculated from the signal of the rotation sensor 1912 so that the second rotor 1310 can rotate at the speed n [rpm] with the torque 2t [N • m]. That is, the torque control section 1400 is energized by the inverter 400 to generate an additional torque t as a motor as indicated by cross-hatching in Fig. 2C. The rotation of the second rotor 1310 is transmitted through the internal gear 1332a of the rotor frame 1332, the input gear 1811 and the reduction section 1800 to the output shaft 1860.

Thus, the power of the engine which rotates at a speed 2n [rpm] with a torque t [N • m] as shown in Fig. 2A can be applied to the vehicle runs at a speed n [rpm] with a torque 2t [N • m] as shown in Fig. 2D.

The speed control section 1200 can operates as a motor for driving the vehicle wheel if the vehicle requires speed higher than the speed of the engine 100. The torque control section 1400 can operate as a generator for charging battery if the engine torque exceeds torque required by the vehicle.

The convertion of the torque and speed between the engine and the vehicle wheel can be carried out also when the power of the engine and load of the vehicle wheel is different in the same manner as described above. For example, when the vehicle runs on a steep uphill slope, the control unit 500 controls the inverters 200 and 400 to supply electric power to the control coils 1211 and 1411 thereby to assist the engine to drive the vehicle wheels as required. On the other hand, when the vehicle runs on a steep down hill, the control unit 500 controls the inverter 200 and 400 to charge electric power generated by the control coils 1211 and 1411 to the battery.

When the vehicle needs further slow down, the speed control section 1200 connects the wheel to the engine 100 as a brake or a compressor. Thus, torque

control section 1400 is not required to have large braking power, resulting in a compact size.

(Second Embodiment)

A system for driving an electric vehicle according to a second embodiment is described with reference to Fig. 4.

The same reference numeral indicates the same or substantially the same part or portion hereinafter and, therefore, detailed description is omitted from descriptions of the following embodiments.

The second rotor 1310 according to the second embodiment has squirrel-cage-conductors 1227 and 1427 instead of the permanent magnets. Accordingly, the second rotor 1310 operates as an induction motor instead of a synchronous motor in the first embodiment.

A cylindrical non-magnetic layer 1350 is disposed between the squirrel-cage-conductors in order to prevent magnetic interference between the speed control section 1200 and the torque control section 1400, as shown in Fig. 4 which is a cross-sectional view illustrating a main portion of the T-S converter 1000.

Since the T-S converter according to the second embodiment is composed of the induction type second rotor 1310, the rotation sensors 1911 and 1912 can be replaced with a crank angle sensor or vehicle speed sensor disposed near the vehicle wheel.

Either one of the squirrel-cage conductors 1227 and 1427 of the second rotor 1310 can be replaced with the permanent magnets as described with regard to the first embodiment.

(Third Embodiment)

A T-S converter 2000 according to a third embodiment is described with reference to Fig. 5 and Figs. 6A, 6B, 6C and 6D.

A gear 210d is formed on the end of an output shaft 210 of the engine 100 to be in mesh with an internal gear 2332d formed in a frame 2332 of the second rotor 1310 so that the engine power is transmitted to the second rotor 1310 directly. The first rotor 1210 is carried by a shaft 2213 which is disposed in alignment with, but separate from, the engine output shaft. A sun gear 2213d of the speed reduction section 1800 is formed at an end of the shaft 2213 opposite the engine 100.

Driving power is transmitted from the first rotor 1210 through the gear 2213d to the planetary gear 1820. Then, after the rotational speed of the planetary gear 1820 is reduced by the internal gear 1830, the driving power is transmitted through the planetary gear shaft 1840 and the planetary carrier 1861 to the output shaft 1860. The output shaft 1860 is rotatably supported by the bearing 1516 which is fitted to a boss portion of a frame 2730 of the speed reduction section 1800. The internal gear 1830 is fixed to the frame 2730 via the fixing member 1835. The cover case 1920, the rotation sensors 1911 and brush holder 1610 are disposed in the frame 2730 together with the reduction section 1800.

Operation of the T-S converter 2000 is described with reference to Fig. 5, Figs. 6A through 6D and Fig. 7.

When the engine 100 rotates at a speed n [rpm] with a torque 2t [N • m] as shown in Fig. 6A and the vehicle runs at a speed 2n [rpm] with a torque t [N • m] as shown in Fig. 6D, the engine rotation is transmitted from the output shaft 210 and a coupling (not shown) through the internal gear 2332d to the second rotor 1310. The inverter 400 supplies the stator control coil 1411 of the torque control section 1400 with AC control current at timing calculated from the signal of the rotation sensor 1912 so that the second rotor 1310 can rotate at the speed n [rpm] with the torque t [N • m]. That is, the torque control section 1400 changes the torque 2t [N • m] transmitted from the engine 100 to t [N • m] as shown in Fig. 6b while maintaining the speed n [rpm] and generates electric power which corresponds to tn [Nm][rpm]. The generated power is supplied from the control coil 1411 to the battery 600 through the inverter 400.

Then, the torque t of the second rotor 1310 is transmitted to the first rotor 1210 of the speed control section 1200 through the permanent magnets 1220 disposed on the inner periphery of the second rotor 1310.

The rotational speed n [rpm] of the first rotor 1210 is changed to 2n [rpm] by induction force or electromagnetic force of the speed control section 1200 to correspond to the vehicle speed and transmitted to the vehicle wheel 1310 as shown in Fig. 6C. When the speed of the second rotor 1310 is changed from n [rpm] to 2n [rpm] while maintaining the same torque t as shown in Fig. 6C, the direction of the rotation of the first rotor is the same as the direction of the rotation of the second rotor 1310 and, therefore, the T-S converter 2000 operates in the motor mode. The rotation of the first rotor 1210 relative to the second rotor 1310 is detected by the rotation sensors 1911 and 1912 to energize the control coil 1211 of the first rotor 1210 at timing calculated on the basis of the relative rotation, and electric power is supplied to the speed control section 1200 by the inverter 200. The first rotor 1210 rotates at the speed 2n [rpm] with the torque t [N • m] by consuming energy nt [N • m][rpm] of the battery as indicated by cross hatching in Fig. 6C.

Thus, the power of the engine which rotates at a speed n [rpm] with a torque 2t [N • m] as shown in Fig. 6A can be applied to the vehicle which runs at a speed 2n [rpm] with a torque t [N • m] as shown in Fig. 6D.

The speed control section 1200 can operate as a motor when the engine speed is higher than the vehicle speed, and the torque control section 1400 can operates as a generator when the vehicle load is larger than the engine torque, as described with regard to the first embodiment.

(Fourth Embodiment)

A T-S converter according to a fourth embodiment is described with reference to Fig. 7.

The second rotor 1310 according to the fourth embodiment has squirrel-cage-conductors 1227 and 1427 instead of the permanent magnets of the T-S converter 2000 according to the third embodiment shown in Fig. 5. Accordingly, the second rotor 1310 operates as an induction motor instead of a synchronous motor in the first embodiment as described with regard to the second embodiment.

A cylindrical non-magnetic layer 1350 is disposed between the squirrel-cage-conductors in order to prevent magnetic interference between the speed control section 1200 and the torque control section 1400, as shown in Fig. 4 for the second embodiment.

(Fifth Embodiment)

A T-S converter 3000 according to a fifth embodiment of the present invention is described with reference to Fig. 11. The T-S converter 3000 is composed of a speed control section 3200 and a torque control section 3400 disposed tandem on an axis.

The speed control section 3200 is structured as a three-phase synchronous rotary electric machine and is composed of housings 3240 and 3241, a cylindrical second rotor 3220 supported by the housings 3240 and 3241 through bearings 3251 and 3252 and a first rotor.

The second rotor 3220 is connected to the output shaft 110 of the engine 100 and carries a shaft 3213 of a first rotor 3210 in line with the output shaft 110 of the engine 100 via bearings 3253 and 3254. The second rotor has a stator core 3222, a three-phase-winding coil (known as a coil of the three-phase rotary machine) 3221 and a pair of end frames 3228 and 3229.

The first rotor 3210 has a shaft 3213, a rotor core 3211 made of a soft iron which is fixed to the shaft 3213, magnetic poles having permanent magnets secured to the outer periphery of the core by a non-magnetic ring 3215 in structure well-known as a permanent magnet rotor of a generator.

An annular slip ring member 3630 is fixed to a radially inner portion of the end frame 3228. The slip ring member 3630 has three slip rings, which are connected to each phase winding of the coil 3221 and supported by an insulating member.

A brush member 3260 is connected to the inverter 200 and fitted to an opening which is formed on an end portion of the housing 3240. The brush member 3260 has a brush holder, three brushes 1620 slidably disposed in the brush holder and springs which bias the brushes against the slip rings. The inverter 200 supplies the coil 3221 with control current through the brush member 3260 and the slip ring member 3630.

A rotational speed sensor 3281 is disposed between an inner surface of the housing 3241 and an outer surface of the end frame 3229 to detect rotational speed of the second rotor 3220 and to send a signal to the inverter control unit 500 (which is described before). A rotational speed sensor 3282 is disposed between the outer surface of the housing 3241 and the shaft 3213 of the first rotor 3210 to detect rotational speed of the first rotor 3210 and send a signal to the inverter control unit 500.

The speed control section 3200 can be structured as an induction type rotary machine which provides squirrel cage conductors instead of the permanent-magnet poles.

The torque control section 3400 is a three-phase synchronous rotary machine. The torque control section 3400 has a third rotor 3410, housings 3440 and 3441 which support the third rotor 3410 via bearings 3451 and 3452, a stator core 3420 secured to the housing 3440 and a stator coil 3421 which is connected to the inverter 400. The third rotor 3410 has a shaft 3413 connected in line to the shaft 3213 of the first rotor 3210 by a coupling member 3800, a rotor core 3411 made of soft iron and a plurality of magnetic poles 3412 having permanent magnets supported by a non-magnetic ring 3415 in structure well-known as a permanent magnet rotor.

A rotational speed sensor 3481 is disposed between an inner surface of the housing 3440 and an end surface of the third rotor 3410 to detect rotational speed of the third rotor 3410.

When the engine 100 rotates, the second rotor 3220 is driven by the engine 100 and drives the first rotor 3210 and the third rotor which is connected thereto by electromagnetic force generated by the coil 3221 to rotate at a set rotational speed. The coil 3221 is controlled by the inverter 200 in a manner readily understood from the previous description. The inverter 400 supplies the stator coil 3421 with a control current so that the third rotor 3410 drives the vehicle wheels 700 with a set torque at the set speed in the same manner described before.

(Sixth Embodiment)

A T-S converter 4000 according to a sixth embodiment of the present invention is described with reference to Fig. 12.

The input shaft 1213 is connected to the engine output shaft 110 at the same side the speed reduction section 4800 is connected to the vehicle wheels 700 via a differential gear 900 in this embodiment. As a result, the T-S converter 4000 can be mounted in a limited space around the engine.

The speed reduction section 4800 is composed of a small gear 4810 and a large gear 4820 which is carried by a gear shaft 4840 and in mesh with the small gear 4810. The differential gear 900 is a common type which is composed of a large gear 830, a gear box 910 and differential gears 920 and 930 connected to the vehicle wheels 700.

The small gear 4810 of the speed reduction section 4800 is in mesh with the internal gear 1332a of the boss portion of the rotor frame 1332 which rotates as an output shaft of the T-S converter around the input shaft 1213, and the large gear 4820 of the speed reduction section 4800 is in mesh with the large gear 830 of the differential gear 900.

The rotation sensors 1911 and 1912 are disposed at a side remote from the output shaft of the engine and the output member (1332a) of the second rotor so that noise caused by torque transmission between the engine and the converter and between the converter and the vehicle wheels can be prevented from transmitting to the rotation sensors 1911 and 1912.

The brushes 1620 and slip rings 1630 are also disposed remote from the output shaft so that chattering of the brushes caused by the torque transmission can be prevented.

The speed reduction section 4800 can be composed of bevel gears instead of the spur gear.

(Seventh Embodiment)

A T-S converter 5000 according to a seventh embodiment of the present invention is described with reference to Fig. 13 and Fig. 14.

A gear 117 is carried by the output shaft 110 of the engine 100 through serrations 110a, and is in mesh with a gear 120 which is connected to the frame 1332 of the second rotor 1310 through serrations 1332a so that the engine power is transmitted to the second rotor 1310 directly as shown in Fig. 14. The first rotor 1210 is carried by the shaft 1213 which is separated from the engine output shaft. A speed reduction section 5800 is composed of a large gear 5820 which is secured to a portion of the engine 100 and is in mesh with the large gear 830 of the differential gear 900 described before. A gear 1213a is formed at the end of the shaft 1213 on the side of the engine 100 and is in mesh with the large gear 5820.

Driving power is transmitted from the first rotor 1210 through the gear 1213a, the large gear 5820 and the deferential gear 900 to the vehicle wheels 700.

(Variations of the Second Rotors)

Structural variations of the second rotor 1310 are described briefly with reference to Figs. 13A through 13H.

The number of the internal magnets 1220 of the second rotor 1310 is different from the number of the external magnets 1420, and the internal magnet is wider than the external magnet 1420 as shown in Fig. 15A.

The angular position of the internal magnets 1220 is different from that of the external magnets 1420 as shown in Fig. 15B.

The number and the angular position of both internal and external magnets are the same as shown in Fig. 3 and Fig. 15C, however, the magnetic polarity on the same angular position is specific. That is, if one of the internal magnets 1220 facing the first rotor 1210 is polarized S, a corresponding one of the external magnets 1420 facing the stator 1410 is polarized N and the adjacent one of the internal magnets 1220 is polarized N and also the adjacent one of the external magnets 1420 corresponding to the last is polarized S so that the composite magnetic flux $\Phi 1$ generated by both internal and external magnets interlinks both coils 1211 and 1411 as shown in Fig. 15C. As a result, differential magnetic flux $\Phi 2$ passing between both coils 1211 and 1411 is reduced and radial thickness of the rotary yoke 1311 can be reduced.

The above effect can be attained also by a structure shown in Fig. 15D. The internal and external magnets 1220 and 1420 are disposed in cavities hollowed out of the rotary yoke 1311 which is made of laminated thin steel-plates so that the non-magnetic ring 1425 can be omitted. Since the outer periphery of the rotary yoke can be lathed, the gaps between the first and second rotors 1210 and 1310 and between the second rotor 1310 and the stator core 1412 can be reduced, thereby reducing the size of the T-S converter.

The angular position of the external magnets 1420 is shifted from the angular position of the internal magnets 1220 in the second rotor 1310 as shown in Fig. 15E.

Flat magnets are used for the internal and external magnets 1220 and 1420 in the second rotor 1310 as shown in Fig. 15F.

Although the present invention has been fully described in connection with the preferred embodiment thereof with reference to the accompanying drawings, it is to be noted that various changes and modifications will become apparent to those skilled in the art. Such changes and modifications are to be understood as being included within the scope of the present invention as defined by the appended claims.

A T-S converter (1000) is composed of a first rotor (1210) which has a first control coil (1211), a second rotor (1310) and a stator which has a second control coil (1411). The second rotor (1310) has a first magnetic field member (1220) such as permanent magnets which supplies the first control coil (1211) with magnetic field and a second magnetic field member (1420) such as permanent magnets which supplies the second control coil (1411) with magnetic field. The first and second control coils are energized to drive the second rotor (1310) to rotate at a set speed with a set torque according to vehicle running condition. The first and the second control coil are also energized to generate battery charging current when the vehicle speed is decreased and the second rotor (1310) is driven by the vehicle wheels.

Claims

1. A system for driving an electric vehicle having a battery (600), an engine (100) and a vehicle drive member (700, 900) comprising:

   a speed-torque converter (1000, 2000, 3000, 4000, 5000) having a housing (1710, 1720, 1730, 1920), an input shaft (1213, 1332a 3210) connected to said engine, an output shaft (1860, 3413) connected to said vehicle drive member, a first rotor (1210, 3220) having a first control coil (1211, 3221), a stator (1410, 3420) having a second control coil (1411, 3421), a second rotor (1310, 3210, 3410) having a first member (1220, 3212) for generating magnetic field interlinking said first control coil and a second member (1420, 3412) for generating magnetic field interlinking said second control coil;

   means (1911, 1912, 3281, 3481) for detecting rotation of said first rotor and said second rotor; and

   means (200, 400, 500), connected to said battery, said first and second control coils and said rotation detecting means, for supplying said first and second control coils with control electric current according to said rotation of said first and second rotors to convert rotational speed and torque of said engine and drive said vehicle drive member at a set rotational speed with a set torque.

2. A system for driving an electric vehicle as claimed in claim 1, wherein said first rotor is connected to input shaft and said second rotor is connected to said output shaft.

3. A system for driving an electric vehicle as claimed in claim 1, wherein said second rotor is connected to said input shaft and said first rotor is connected to said output shaft.

4. A system for driving an electric vehicle as claimed in any one of claims 1, 2 and 3, wherein said speed-torque converter further comprises a speed reduction means (1800,4800, 5800) connected in series with said output shaft.

5. A system for driving an electric vehicle as claimed in any one of claims 1, 2 and 3, wherein said speed-torque converter further comprises a planetary-gear speed reduction means (1812, 1820, 1830) connected in series with said output shaft.

6. A system for driving an electric vehicle as claimed in any one of claims 1, 2 and 3, wherein said control current supplying means comprises means for controlling said engine to operate as a brake member when said vehicle drive member drives said output shaft.

7. A system for driving an electric vehicle as claimed in any one of claims 1, 2 and 3, wherein said first rotor, said second rotor and said stator are disposed coaxially with each other on a common same plane.

8. A system for driving an electric vehicle as claimed in any one of claims 1, 2 and 3, wherein said first rotor is disposed radially inside said second rotor and said second rotor is disposed radially inside said stator coaxially.

9. A system for driving an electric vehicle as claimed in any one of claims 1, 2 and 3, wherein at least one of said first and second members comprises permanent magnets.

10. A system for driving an electric vehicle as claimed in any one of claims 1, 2 and 3, wherein at least one of said first and second members comprises a squarrel cage conductor.

11. A system for driving an electric vehicle as claimed in any one of claims 1, 2 and 3, wherein said first and second members comprise squarrel cage conductors and said second rotor comprises a nonmagnetic member disposed between said first and second members.

12. A system for driving an electric vehicle as claimed in any one of claims 1, 2 and 3, wherein said control electric current supplying means comprises a first inverter (200) connected to said first control coil (1211, 3221), a second inverter (400) connected to said second control coil (1411, 3421) and an inverter control unit (500) connected to said rotation detecting means (1911, 1912, 3281, 3481) and to said first and second inverters for controlling timing of said control electric current supplied to said first and second control coils by said inverters according to rotation of said first and second rotors.

13. A system for driving an electric vehicle as claimed in any one of claims 1, wherein said input shaft and said output shaft are disposed at same side of said housing.

14. A system for driving an electric vehicle as claimed in claim 13, wherein said input shaft and said output shaft are disposed caxially with each other.

15. A system for driving an electric vehicle as claimed in claim 14, wherein said rotation detecting means is disposed in said housing remote from said input shaft and said output shaft.

16. A system for driving an electric vehicle as claimed in claim as claim 15, wherein said control electric current supplying means comprises brushes and

slip rings disposed in said housing remote from said input shaft and said output shaft.

17. A system for driving an electric vehicle as claimed in any one of claims 16, wherein said speed-torque converter further comprises a speed reduction means connected in series with said output shaft.

18. A system for driving an electric vehicle having a battery (600), an engine (100) and vehicle differential gears (900) comprising:

a speed-torque converter (4000, 5000) having a housing (1710, 1720, 1730, 1920), an input shaft (1213, 1332a) disposed in said housing and connected to said engine at a side, an output shaft (1213, 1332a) disposed coaxially with said inpput shaft and connected to said vehicle differential gears at the same side, a first rotor (1210) having a first control coil (1211), a stator (1410) having a second control coil (1411), a second rotor (1310) having a first member (1220) for generating magnetic field interlinking said first control coil and a second member (1420) for generating magnetic field interlinking said second control coil;

means (1911, 1912) for detecting rotation of said first rotor and said second rotor; and

means (200, 400, 500), connected to said battery, said first and second control coils and said rotation detecting means, for supplying said first and second control coils with control electric current according to said rotation of said first and second rotors to convert rotational speed and torque of said engine and drive said vehicle drive member at a set rotational speed with a set torque, last said means comprising means for controlling said engine to operate as a brake member when said vehicle drive member drives said output shaft.

19. A system for driving an electric vehicle as claimed in claim 18, wherein said rotation detecting means is disposed in said housing remote from said input shaft and said output shaft.

20. A system for driving an electric vehicle as claimed in claim as claim 18, wherein said control electric current supplying means comprises brushes and slip rings disposed in said housing remote from said input shaft and said output shaft.

21. A system for driving an electric vehicle as claimed in claim 18, wherein said control electric current supplying means comprises means for generating battery charging current.

22. A system for driving an electric vehicle having a battery (600), an engine (100) and a vehicle drive member (700, 900) comprising:

a speed-torque converter (1000, 2000, 3000, 4000, 5000) having a housing (1710, 1720, 1730, 1920), an input shaft (1213, 1332a 3210) connected to said engine, an output shaft (1860, 3413) connected to said vehicle drive member, a first rotor (1210, 3220) having a first control coil (1211, 3221), a stator (1410, 3420) having a second control coil (1411, 3421), a second rotor (1310, 3210, 3410) having a first member (1220, 3212) for generating magnetic field interlinking said first control coil through a magnetic path and a second member (1420, 3412) for generating magnetic field interlinking said second control coil through the same magnetic path ;

means (1911, 1912, 3281, 3481) for detecting rotation of said first rotor and said second rotor; and

means (200, 400, 500), connected to said battery, said first and second control coils and said rotation detecting means, for supplying said first and second control coils with control electric current according to said rotation of said first and second rotors to convert rotational speed and torque of said engine and drive said vehicle drive member at a set rotational speed with a set torque.

23. A system for driving an electric vehicle as claimed in claim 22, wherein said first member comprises a number of magnetic poles and said second member comprises the same number of the magnetic poles.

24. A system for driving an electric vehicle as claimed in claim 22, wherein said second rotor comprises a laminated core having a plurality of holes for accommodating said first and second members therein.

25. A system for driving an electric vehicle having a battery (600), an engine (100) and a vehicle drive member (700, 900) comprising:

a first electromagnetic rotary unit having an input shaft (1213, 1332a 3210) connected to said engine, a first rotor (1210, 3220) connected to said input shaft and having a first control coil (1211, 3221), a first member (1220, 3212) for generating magnetic field interlinking said first control coil;

a second electromagnetic rotary unit having an output shaft (1860, 3413) connected to said vehicle drive member, a stator (1410, 3420) having a second control coil (1411, 3421) and a second rotor connected to said output shaft and having a second member (1420, 3412) for generating magnetic field interlinking said second control coil, said second rotor being fixed to said first member ;

means (1911, 1912, 3281, 3481) for detecting rotation of said first rotor and said second rotor; and

means (200, 400, 500), connected to said battery, said first and second control coils and said rotation detecting means, for supplying said first

and second control coils with control electric current according to said rotation of said first and second rotors to convert rotational speed and torque of said engine and drive said vehicle drive member at a set rotational speed with a set torque.

26. A system for driving an electric vehicle as claimed in claim 25, wherein said first and second control coils comprise respectively three phase windings.

27. A system for driving an electric vehicle as claimed in claim 26, wherein said first and second members comprise respectively permanent magnets.

28. A system for driving an electric vehicle as claimed in claim 26, wherein at least one of said first and second members comprises a squirrel cage conductor.

29. A method for driving an electric vehicle having a battery (600), an engine (100), a vehicle drive member (700, 900) a first electromagnetic rotary unit having a first control coil and an input shaft (1213, 1332a 3210) connected to said engine, a second electromagnetic rotary unit having a second control coil and an output shaft (1860, 3413) connected to said vehicle drive member, said method comprising steps of;

calculating a set torque Tv and set angular speed ωv of said vehicle drive member;

detecting output torque Te and angular speed ωe of said engine;

supplying said first and second control coils with control electric current according to differences between said torques Tv and Te and between said angular speeds ωv and ωe thereby to convert torque Te and angular speed ωe of said engine and drive said vehicle drive member at said set torque Tv and set angular speed.

30. A method for driving an electric vehicle as claimed in claim 29 further comprising a step of supplying said first and second control coils with control electric current to generate battery charging current when said angular speed ωe of said engine is higher than said set angular speed ωv and said output torque Te of said engine is larger than said set torque Tv.

31. A method for driving an electric vehicle as claimed in claim 29 further comprising a step of supplying said first and second control coils with control electric current to generate driving torque when said angular speed ωe of said engine is lower than said set angular speed ωv and said output torque Te of said engine is lower than said set torque Tv.

32. A method for driving an electric vehicle as claimed in claim 29 further comprising a step of supplying said first and second control coils with control electric current to connect said vehicle drive member to said engine as a load when said angular speed ωe of said engine is lower than said set angular speed ωv and said output torque Te of said engine is smaller than said set torque Tv.

FIG. 1

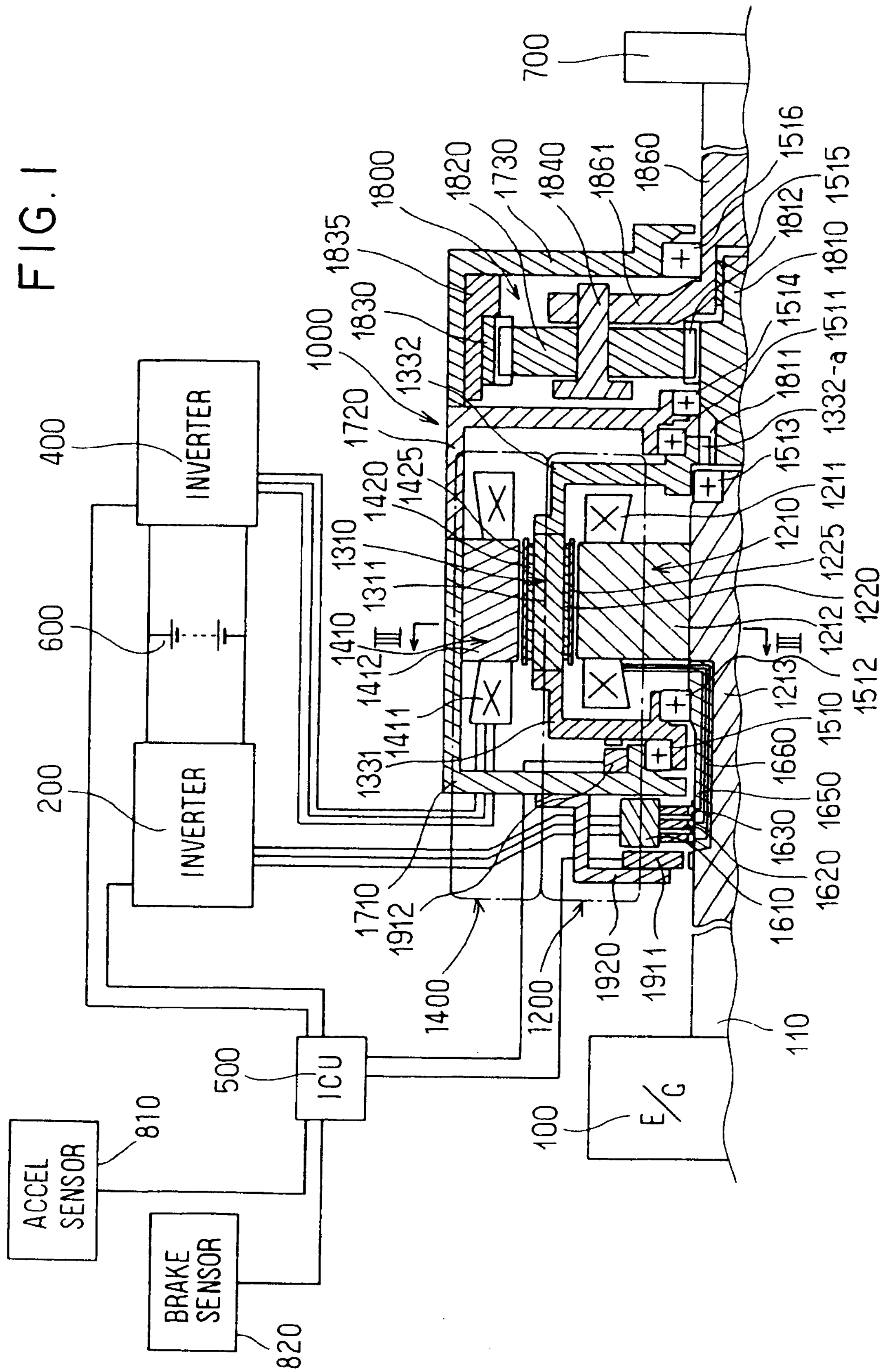


FIG. 2A

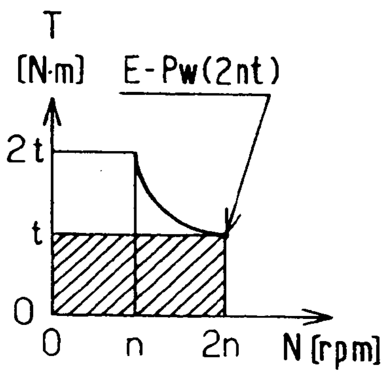


FIG. 2B

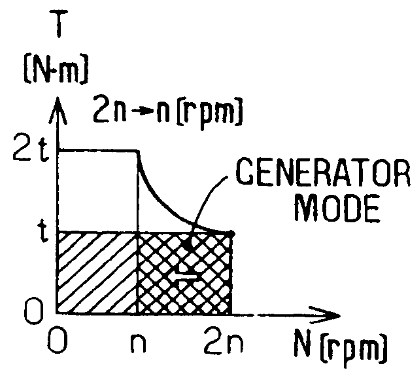


FIG. 2C

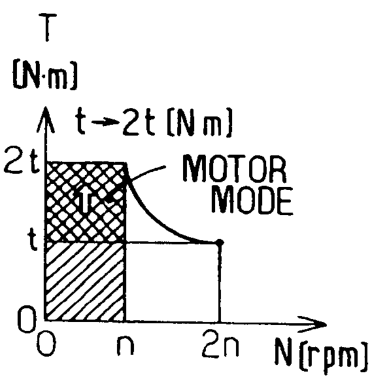


FIG. 2D

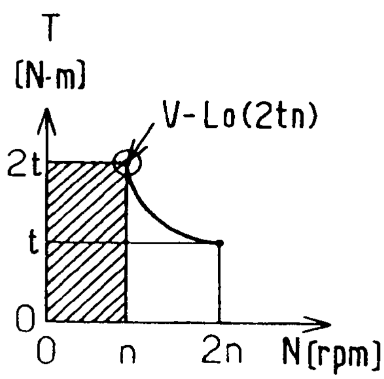


FIG. 3

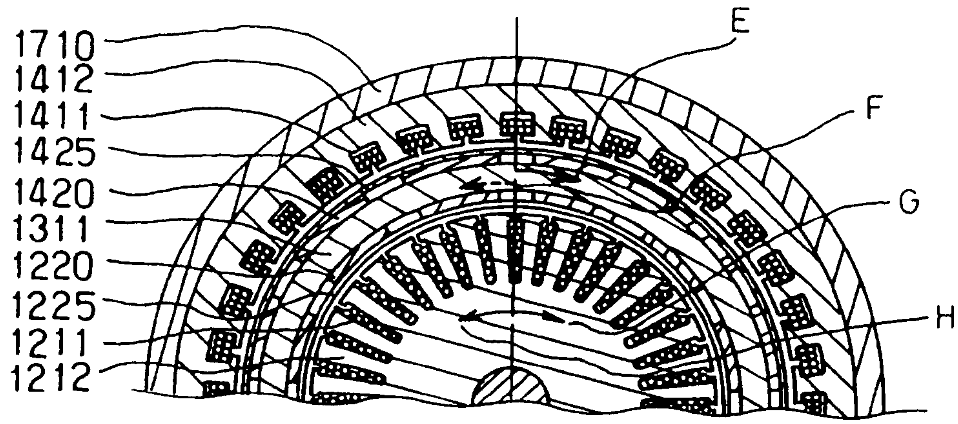

1710
1412
1411
1425
1420
1311
1220
1225
1211
1212
E
F
G
H

FIG. 4

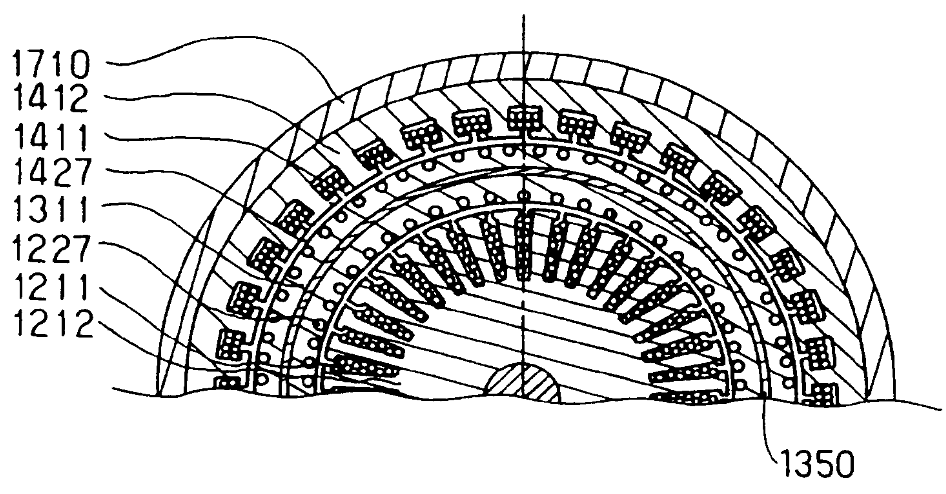

1710
1412
1411
1427
1311
1227
1211
1212
1350

FIG. 5

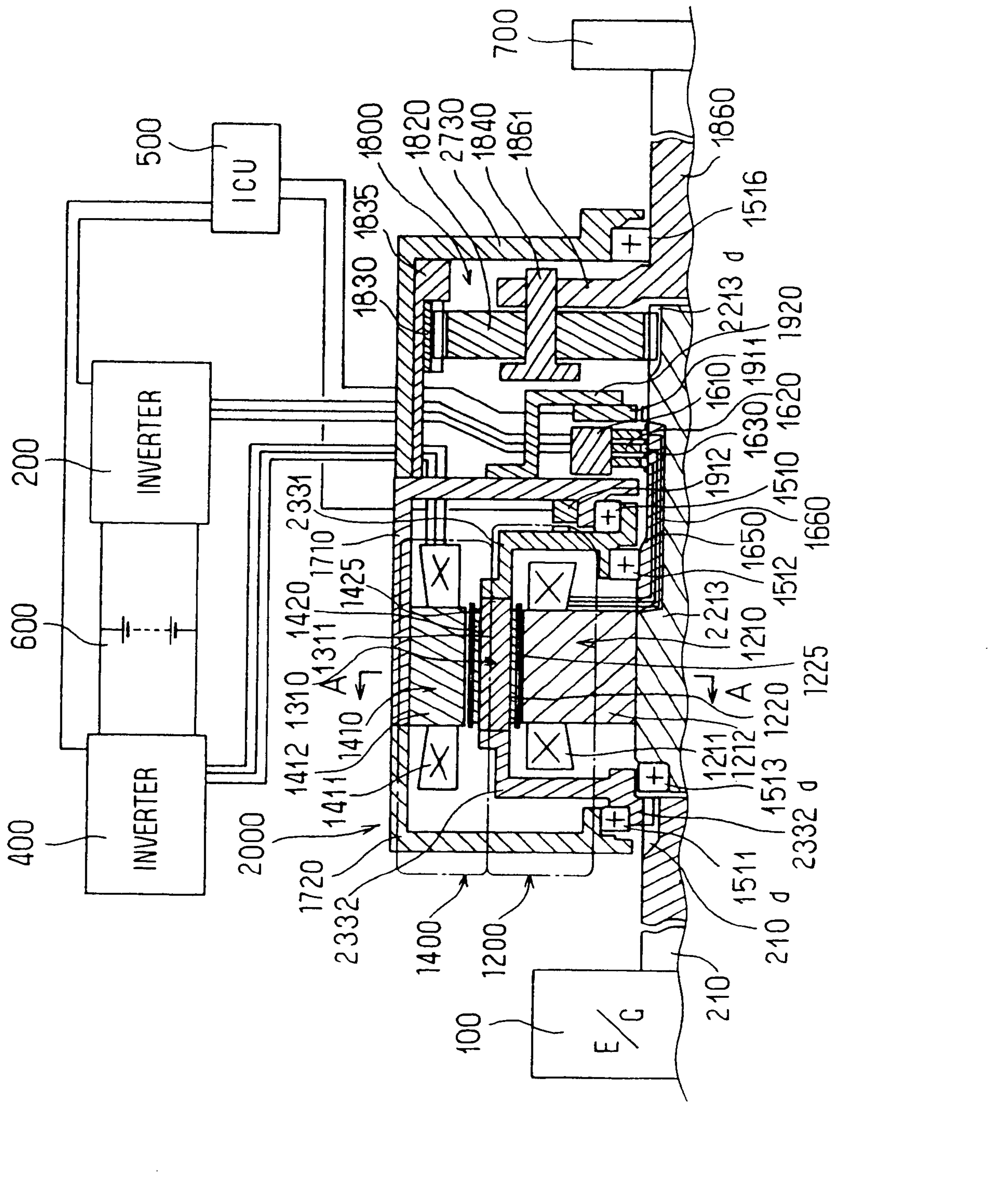

INVERTER
INVERTER
ICU
E/G
400
600
200
500
700
100
1200
1400
2000
1720
2332
210
210 d
1511
2332 d
1513
1212
1211
1220
1225
1210
2213
1512
1650
1660
1510
1912
1630
1620
1610
1911
1920
2213 d
1516
1860
1861
1840
2730
1820
1800
1835
1830
2331
1710
1425
1420
1311
1310
1410
1412
1411
A

FIG. 6A

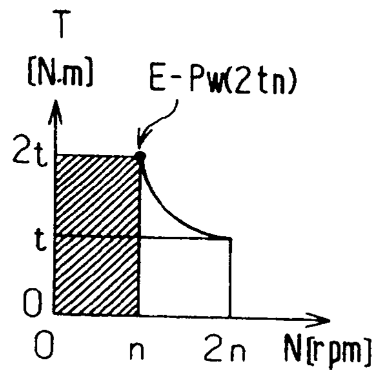


FIG. 6B

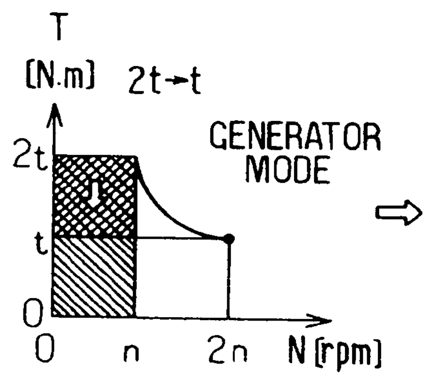


FIG. 6C

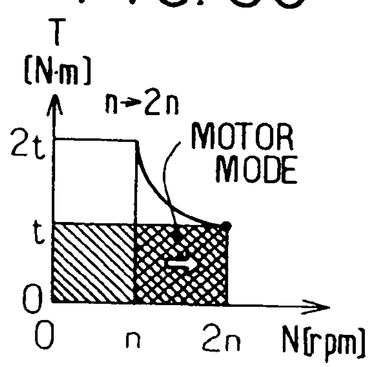


FIG. 6D

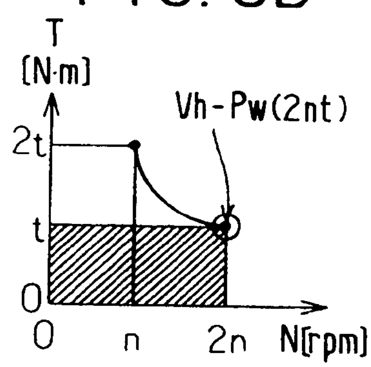


FIG. 7

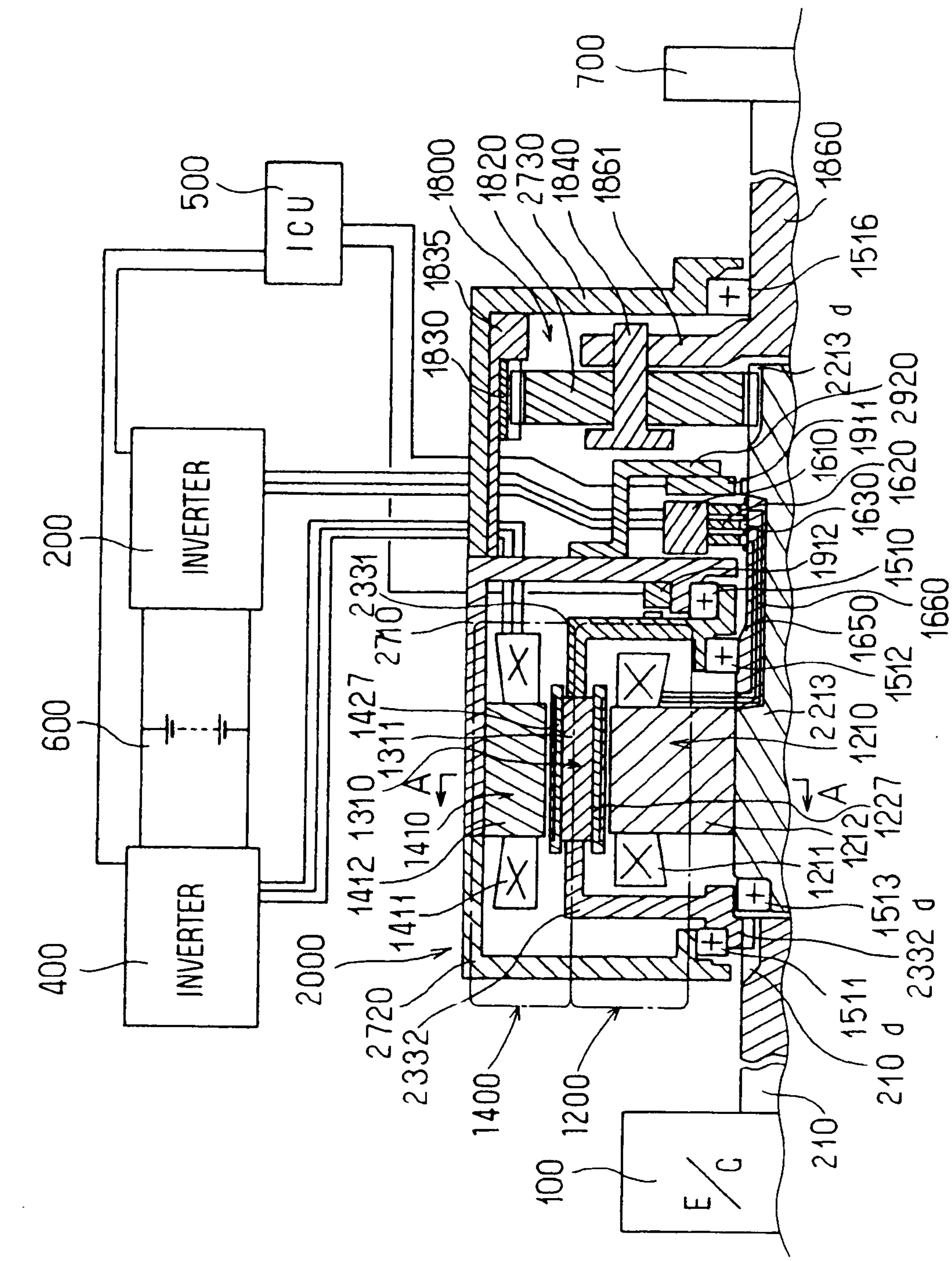

INVERTER
INVERTER
ICU
E/C
400
600
200
500
700
100
210
1400
1200
2000
2720
2332
1411
1412
1410
1310
1311
1427
2710
2331
1830
1835
1800
1820
2730
1840
1861
1860
1516
2213 d
2920
1911
1620
1610
1630
1912
1510
1660
1650
1512
2213
1210
1227
1212
1211
1513
2332 d
1511
210 d
A
A

FIG. 8

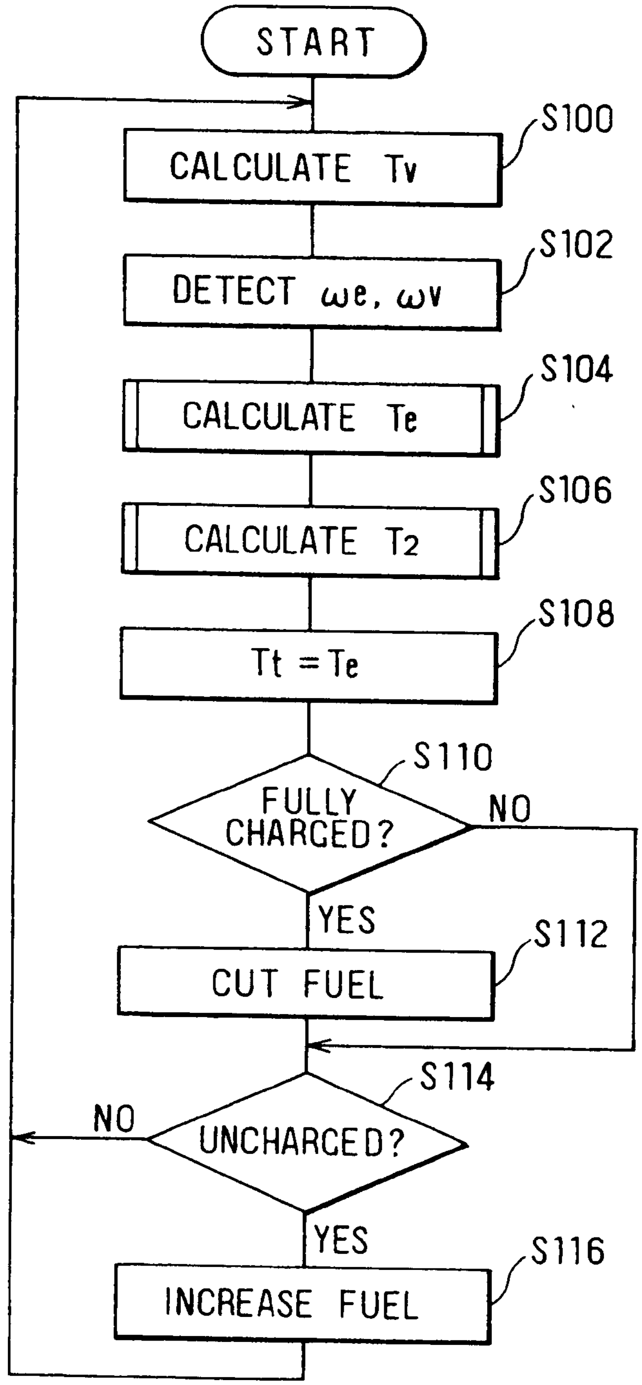

START
CALCULATE Tv
S100
DETECT ωe, ωv
S102
CALCULATE Te
S104
CALCULATE T2
S106
Tt = Te
S108
FULLY CHARGED?
S110
NO
YES
CUT FUEL
S112
UNCHARGED?
S114
NO
YES
INCREASE FUEL
S116

FIG. 9

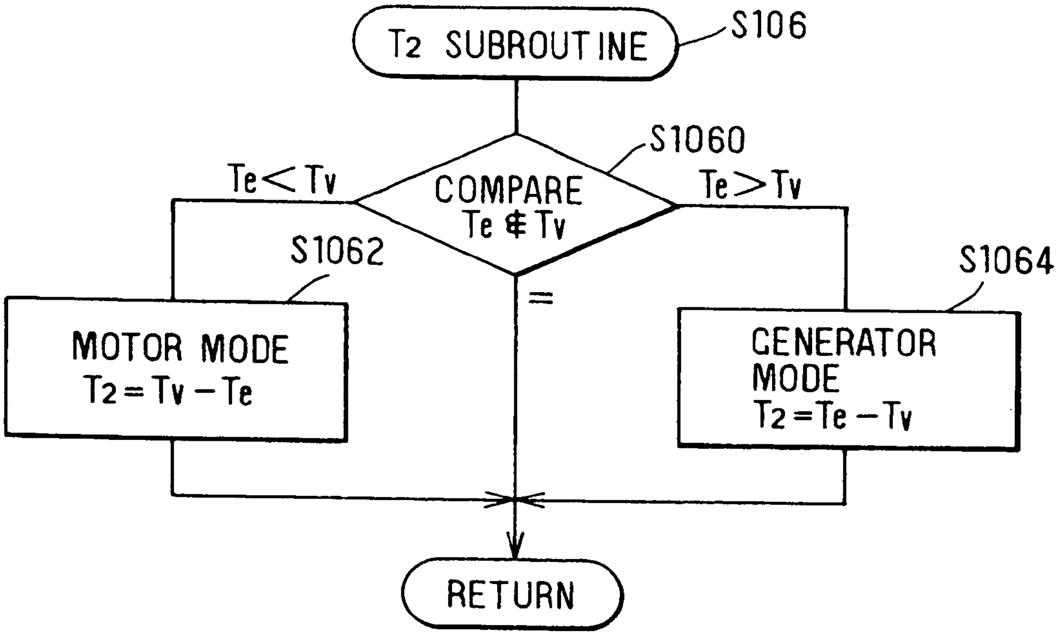

T2 SUBROUTINE
S106
S1060
Te<Tv
COMPARE Te & Tv
Te>Tv
S1062
=
S1064
MOTOR MODE T2=Tv−Te
GENERATOR MODE T2=Te−Tv
RETURN

FIG. 10

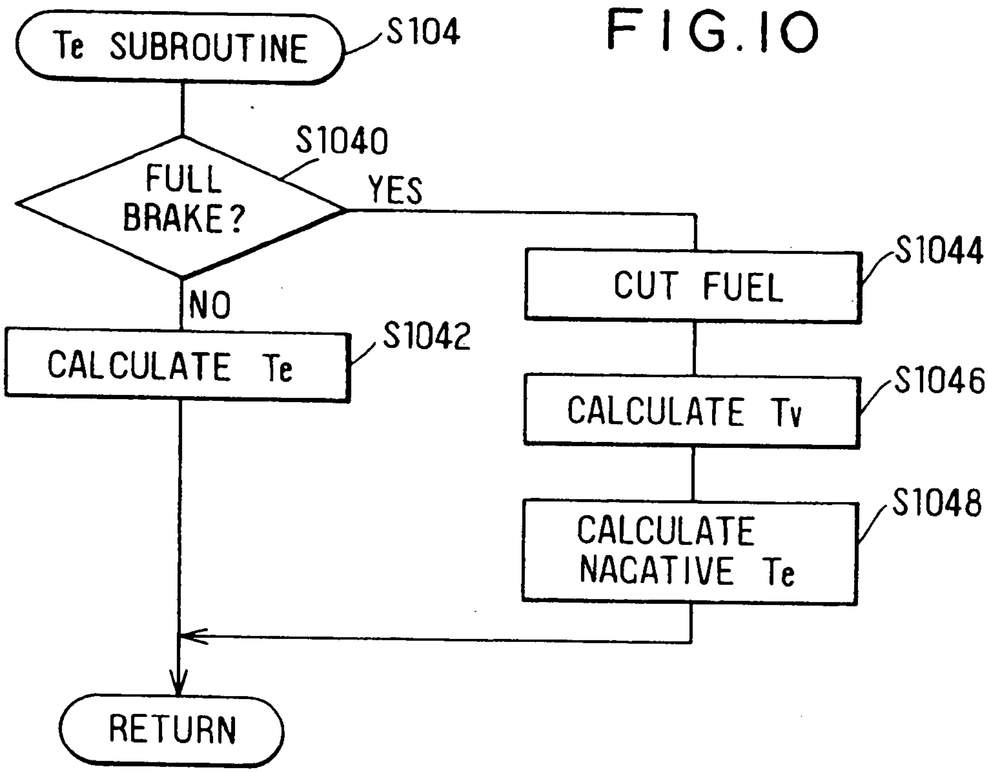

Te SUBROUTINE
S104
S1040
FULL BRAKE?
YES
NO
CUT FUEL
S1044
CALCULATE Te
S1042
CALCULATE Tv
S1046
CALCULATE NACATIVE Te
S1048
RETURN

FIG.11

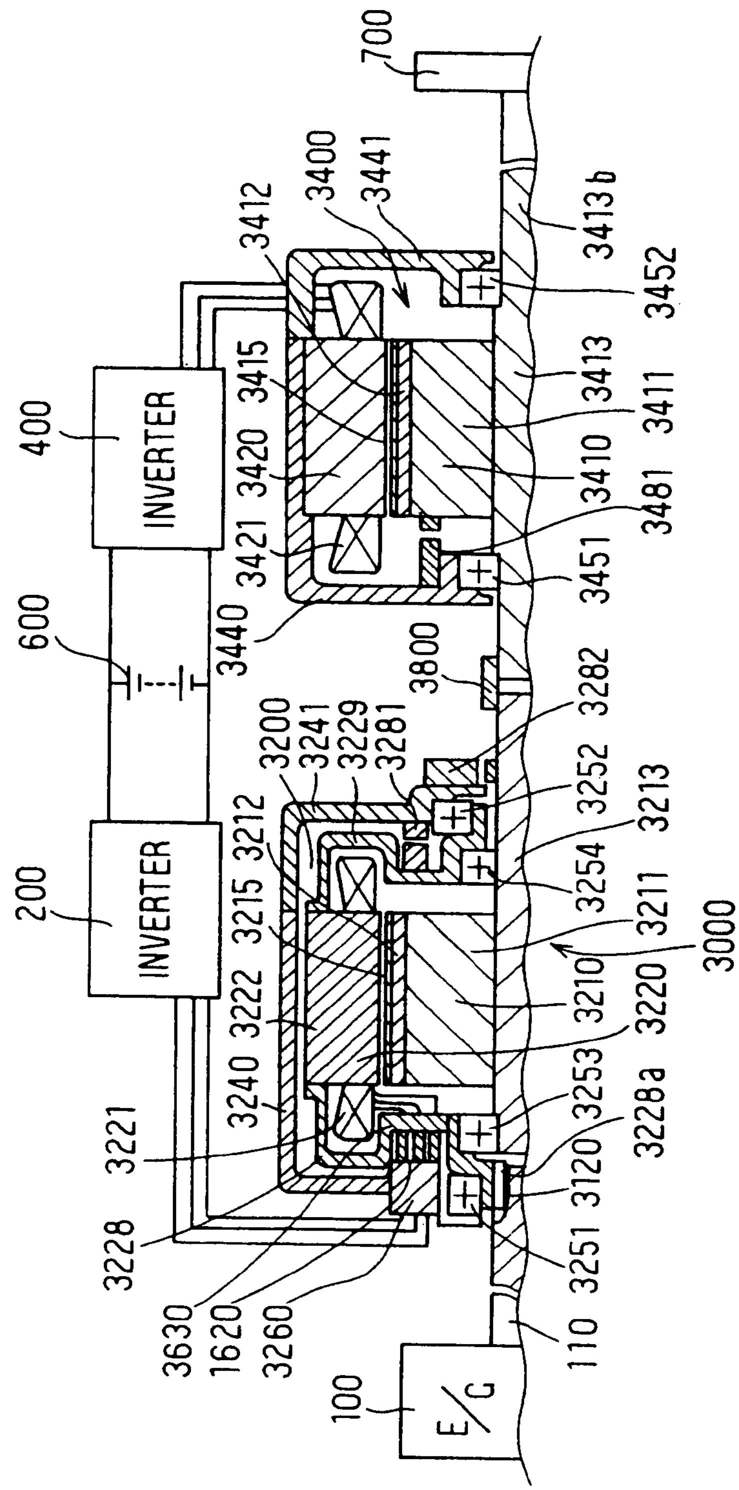

INVERTER
INVERTER
E/G
100
110
200
400
600
700
3000
3120
3200
3210
3211
3212
3213
3215
3220
3221
3222
3228
3228a
3229
3240
3241
3251
3252
3253
3254
3260
3281
3282
3400
3410
3411
3412
3413
3413b
3415
3420
3421
3440
3441
3451
3452
3481
3630
1620
3800

FIG.12

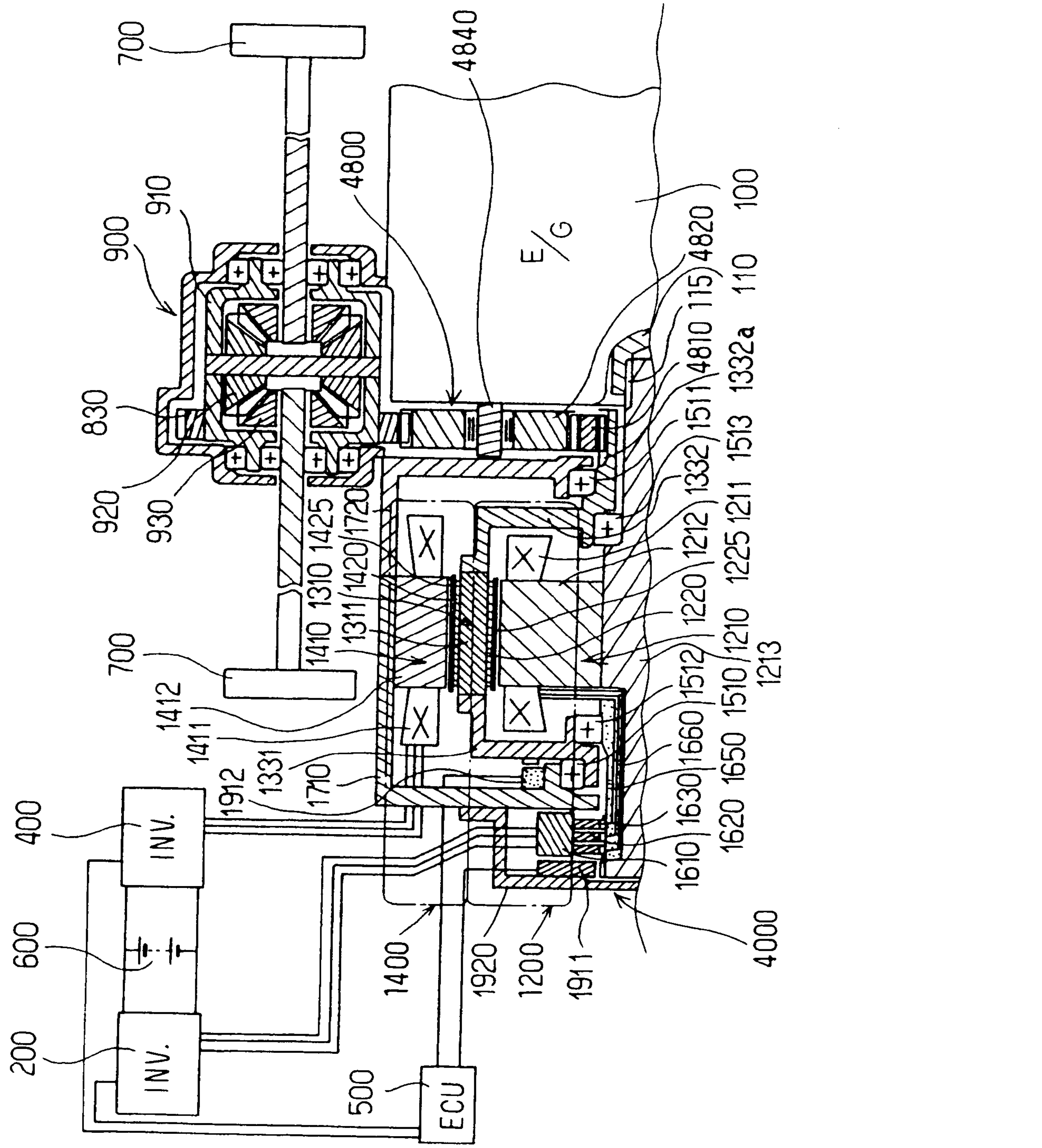

INV.
INV.
ECU
E/G
700
900
910
830
920
930
4800
4840
100
4820
110
115
4810
1332a
1511
1513
1332
1211
1212
1225
1220
1210
1213
1510
1512
1660
1650
1630
1620
1610
4000
1911
1200
1920
1400
1710
1331
1411
1412
1912
1410
1310
1311
1420
1425
1720
400
600
200
500

FIG. 13

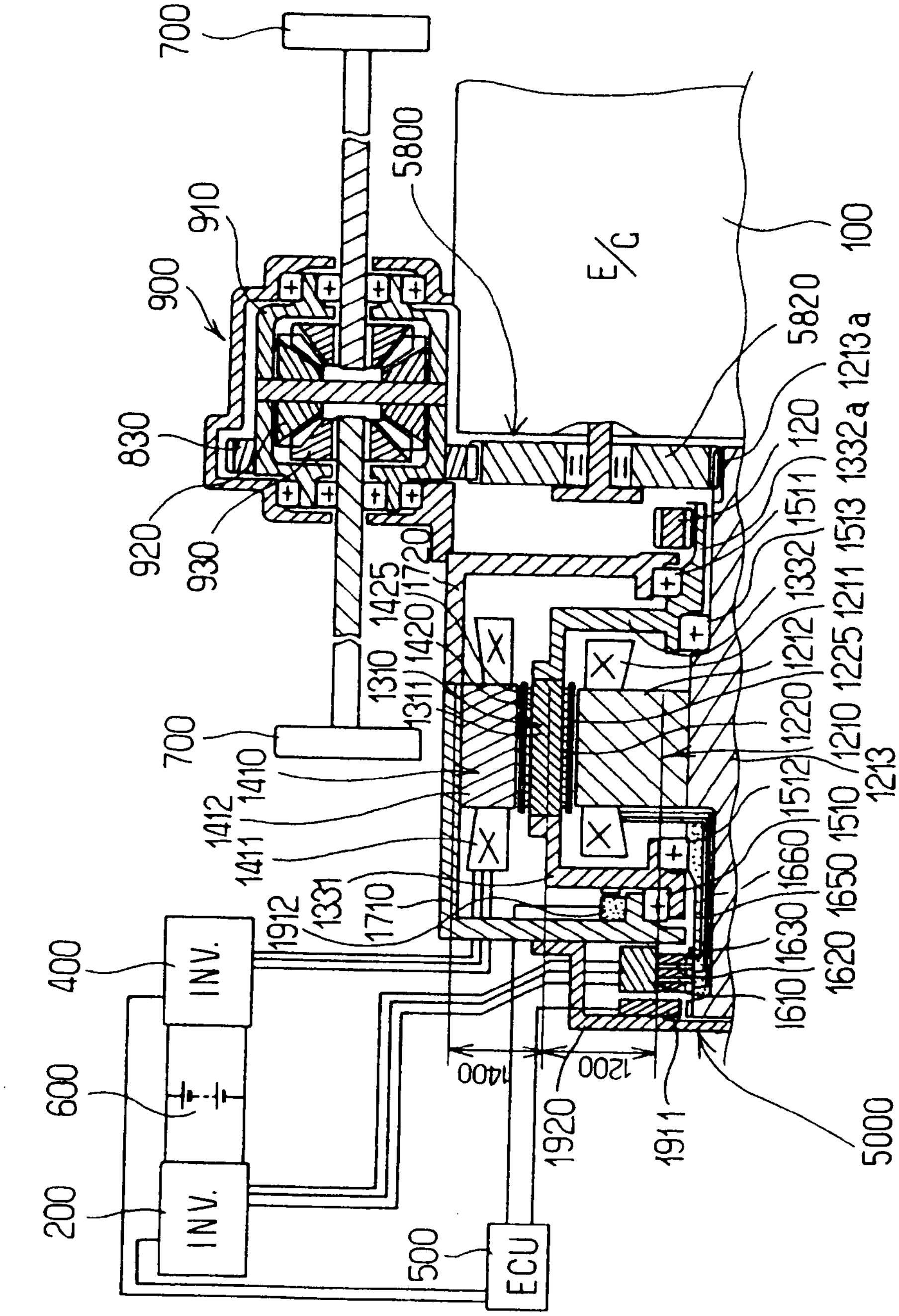

700
5800
910
900
100
E/C
5820
1213a
1332a
120
1511
1513
1332
1211
1225
1212
1220
1210
1213
1512
1510
1660
1650
1630
1620
1610
830
920
930
1720
1425
1420
1310
1311
700
1410
1412
1411
1331
1912
1710
400
INV.
600
200
INV.
500
ECU
1400
1200
1920
1911
5000

FIG.14

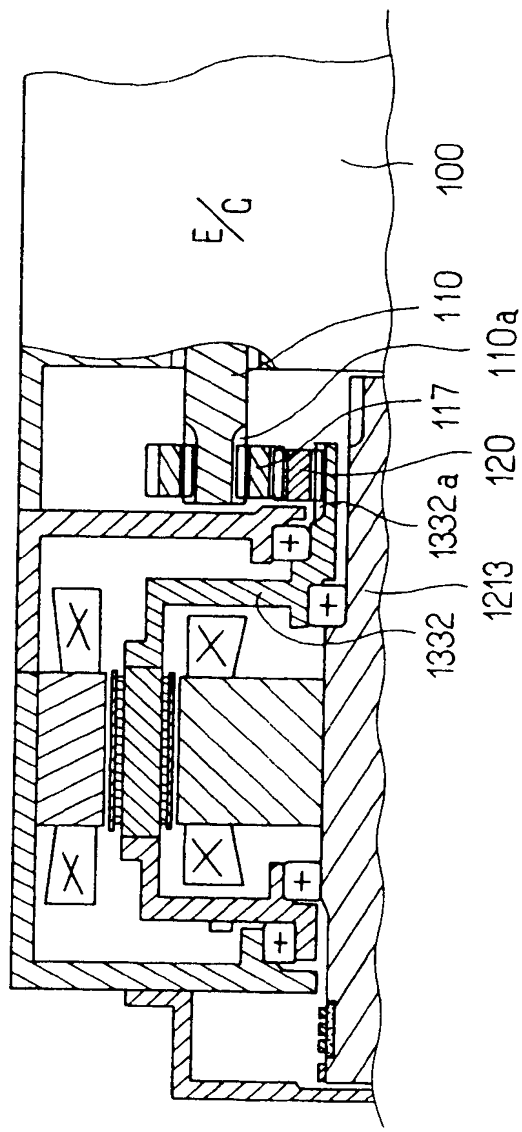


FIG. 15A

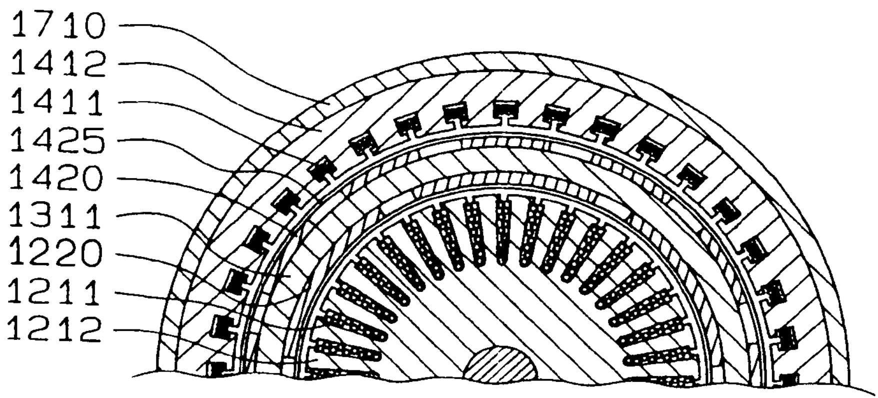


FIG. 15B

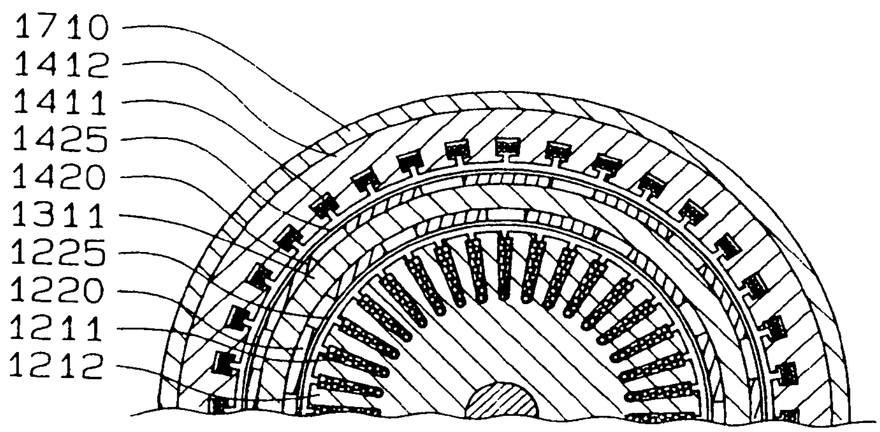


FIG. 15C

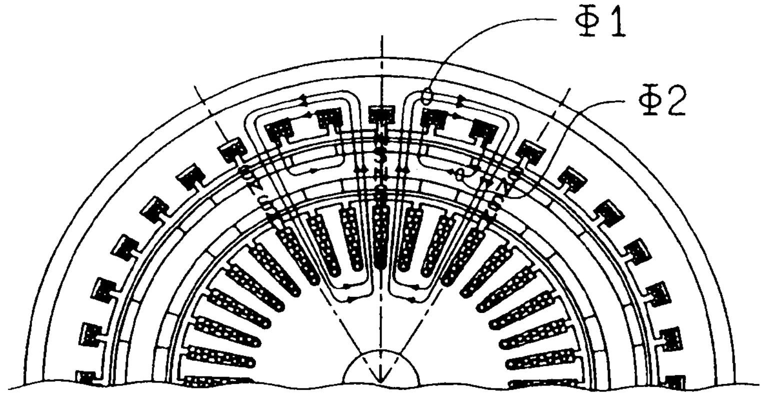


FIG. 15D

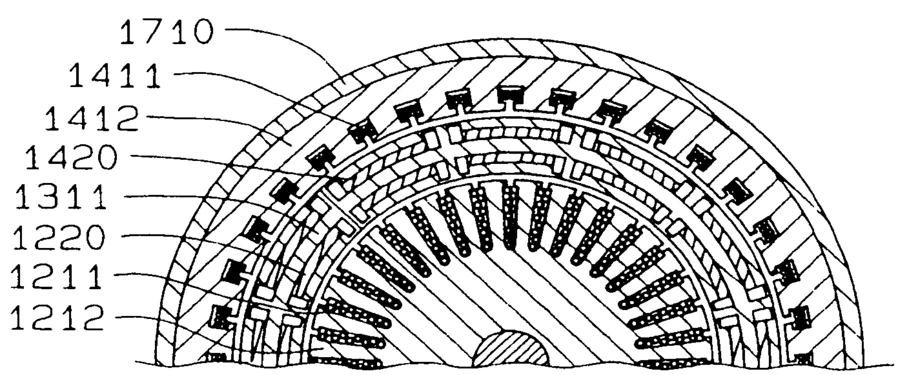


FIG. 15E

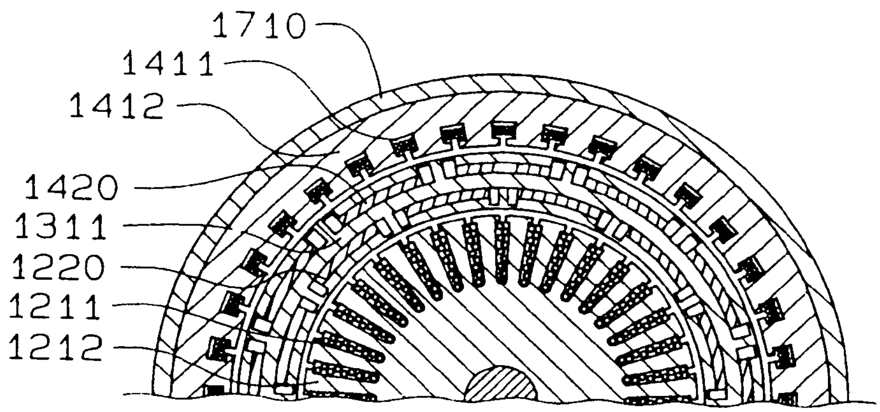
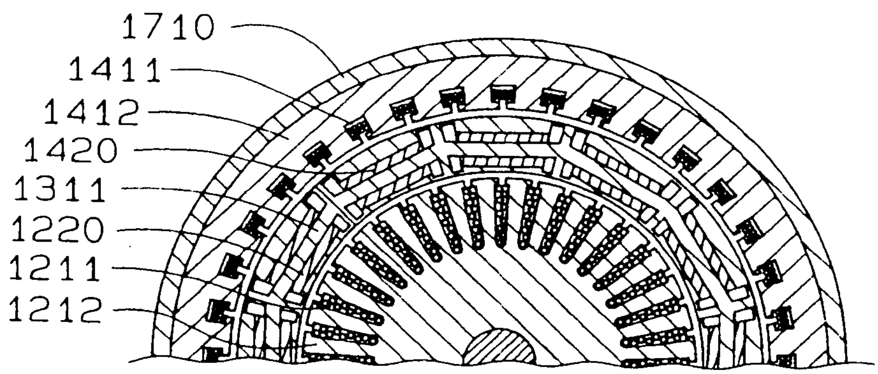


FIG. 15F



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EUROPEAN SEARCH REPORT

Application Number
EP 96 10 1275

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	AU-A-5 840 173 (STEPHEN JOHN ELLIOTT) 30 January 1975 * page 3, line 12 - page 4, line 4; figure 2 * * page 6, line 11 - line 24 *	25-32	H02K51/00 B60L11/12 B60K17/12 B60K6/04
A	US-A-4 407 132 (KAWAKATSU SHIRO ET AL) 4 October 1983 * column 1, line 43 - column 2, line 36; figure 3 *	25,29-32	
A	WO-A-82 00928 (JEFFERIES P) 18 March 1982 * claim 1 *	25-32	
Y	GB-A-2 278 242 (FLACK ROY EDWARD) 23 November 1994 * page 9, line 12 - page 11, line 25; figure 1 * * page 16, line 1 - line 5 *	1,3,6-8, 12,18,22	
Y	US-A-3 789 281 (SHIBATA F) 29 January 1974 * column 1, line 9 - line 23 * * column 8, line 11 - line 60; figures 4,8 *	1,3,6-8, 12,18,22	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H02K B60L B60K
A	US-A-3 683 249 (SHIBATA FUKUO) 8 August 1972 * column 2, line 42 - line 45 *	1,9,10, 27,28	
A	FR-A-2 693 527 (PEUGEOT ;CITROEN SA) 14 January 1994 * page 2, line 19 - line 34 *	13,14	
A	FR-A-2 517 137 (CIBIE PIERRE) 27 May 1983 * page 1, line 15 - page 2, line 2; figure 1 *		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	8 May 1996	Bourbon, R

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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